PLANT PROTECTION OVERSEAS REVIEW

DECEMBER

1952

Vol. 3 No. 3

PLANT PROTECTION

PLANT PROTECTION OVERSEAS REVIEW

A PERIODICAL SURVEY OF NEW DEVELOPMENTS IN THE CONTROL OF PESTS, DISEASES AND WEEDS

PUBLISHED BY

PLANT PROTECTION LTD

BOLTON HOUSE, 61 CURZON STREET, LONDON, W.1

VOL. 3 NO. 3. DECEMBER, 1952

CONTENTS

EDITORIAL

THE possibility of controlling plant diseases by distributing fungicides within the tissues of the host plants is at present being actively investigated at several research institutions. There is evidence that these so-called systemic fungicides may be of great practical significance in the future. We, therefore, welcome in this issue of the " Overseas Review " an article on this very important subject by Dr. P. W. Brian, Head of the Butterwick Research Laboratories of Imperial Chemical Industries Ltd., who is a pioneer in research on systemic fungicides, and under whose direction extensive investigations on these products are at present being carried on.

An article on the results of preliminary experiments on the use of hormone weedkillers in sorghum fields in the Sudan by the Economic Botanist of the Sudan Government and one on recent British developments in taint-free use of BHC by Dr. E. Holmes, Head of Technical Department, Plant Protection Ltd., both of which subjects are of great topical interest and importance, have been reprinted from the " Empire Journal of Experimental Agriculture " and " Agricultural Chemicals " respectively by kind permission of their respective editors.

Pioneer agricultural experiments of great historical interest, with instructive lessons of practical value to investigators at the present day, form the theme of an article by Mr. F. G. Ordish, Agricultural Economist, Plant Protection Ltd., reprinted from " Agriculture " by kind permission of the editor of that journal

We take the opportunity of again inviting our readers to use this journal as a medium of expression of their experiences in and opinions on overseas methods of plant protection in their widest aspects. Contributions on such subjects will be always welcome for publication.

SYSTEMIC FUNGICIDES

By P. W. BRIAN, Sc.D.

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INTRODUCTION

AT present fungicides are used in plant disease control in three ways. These are :—

(1) Fungicides applied to plant surfaces as protectants ; examples of this type of use are control of potato-blight by copper foliage sprays, or seed-dressings applied to prevent soil-borne seedling diseases.

(2) Fungicides applied to plant surfaces to eradicate existing active or latent infections ; examples of this type of use are seed dressings for control of seed-borne disease or application of eradicant foliage sprays in the control of such diseases as leaf-mould of tomato (*Cladosporium fulvum*).

(3) Fungicides applied to loci of infection in the vicinity of some crop which it is desired to protect, as in orchard-floor spraying with dinitro-*o*-cresol to prevent ascospore infection of apples by scab (*Venturia inaequalis*) or the use of formaldehyde as a soil steriliser in glasshouses.

All these are *external* methods of application to the plant. From time to time, especially during the last ten years, plant pathologists have considered the possibility of distributing fungicides *within the tissues* of plants as a means of disease control. The recent discovery of systemic action by a number of insecticides, notably by the organo-phosphorus insecticides, has increased interest in the systemic application of fungicides. Research is proceeding actively at several laboratories. Several different methods of approach have given clear evidence that systemic control of plant diseases can be achieved. As yet nothing like a practical evaluation of such methods has been reported. We are at the very beginning of new developments and it is not possible at present to do more than speculate on their practical significance.

RECENT RESEARCH

It is not possible here to give a complete survey of published work ; instead, a few researches which may be regarded as landmarks have been picked out for special attention.

The modern period of research on systemic fungicides may conveniently be considered to start with the publication by Müller (1926)

of his book *Die innere Therapie der Pflanzen.* In this he exhaustively surveyed all previous work on control of fungus and insect parasites of plants by systemic treatment and described his own researches. His own work was mainly concerned with *Aphis* and but little with fungal diseases, but he made certain observations of general importance. He showed that a wide variety of substances, organic and inorganic, potential fungicides and insecticides, were taken up by plants through cut stems or intact roots. He further showed that nearly all the substances he tried were toxic to plants and that any prospect of the use of systemic methods of application depended upon the existence of an appreciable difference between the dose needed to inhibit the pathogen and the highest dose tolerated by the host plant. None of the substances he tested satisfied that requirement.

Gassner and Hassebrauk (1936) carried out an empirical investigation of a large number of compounds as systemic fungicides; these were applied to the roots of wheat and barley plants growing in sand culture and the leaves were then infected with a foliage rust, *Puccinia triticina* on the wheat and *Puccinia simplex* on the barley. They obtained very definite signs of disease control with a few substances, notably with chloramine-T and picric acid. Both these substances were phytotoxic and no disease control could be obtained with doses harmless to the host plants. The general result of their researches was to cast doubt on the possibility of finding a systemic fungicide safe in use.

Some years later, however, Roach (1939), in the course of his work at East Malling Research Station on tree injection in relation to inorganic nutrition of plants, found that injection of apple branches with sodium thiosulphate conferred on the foliage a considerable degree of resistence to mildew (*Podosphaera leucotricha*). This interesting observation was not followed up.

The next significant development was based on a different method of approach. This was in connection with a vascular disease, the bleeding canker of maple caused by *Phytophthora cactorum.* This disease, like many vascular diseases of plants, is a toxigenic disease; that is, many of the symptoms of the disease are produced by a toxin liberated by the parasite within the host plant. The toxin is translocated within the host producing lesions at a considerable distance from the actual infected tissue. Howard (1941) conceived the idea of introducing substances into maple shoots, by the roots or by stem injection, which would " neutralise " the toxin. He found that diaminoazobenzene hydrochloride would do this—at least he reported reduction of disease symptoms, without any noticeable reduction in the vigour of the pathogen within the host. Since then work on " antidoting toxins " has proceeded steadily at the Rhode Island and Connecticut Agricultural Experiment Stations and field-scale use has been reported, but the usefulness of the technique cannot yet be regarded as proven. Neither can such treatments be considered to be systemic fungicides in the true sense of the term.

Work is at present proceeding in the United States on the use of systemic fungicides for control of *Fusarium* wilts of tomatoes. Successful results have been reported by Dimond (1950). In this investigation plants were grown in sand or water culture and the roots treated with the compound under test; the roots were then, after a suitable interval, washed, inoculated with the *Fusarium* and the plants grown on. Some treatments have given quite effective control of the disease and one is tempted to interpret such results as a systemic fungicidal effect, but as Keyworth (see Marsh, 1952) has pointed out, damage to the roots may result in resistance to infection by root pathogens. Keyworth has in fact shown that a simple heat treatment of the roots *before* infection is effective; the reason for this peculiar effect is not known, possibly the damage to the roots so affects host metabolism that the plant is no longer a suitable substrate for the parasite.

In some respects more encouraging than any of the work described above are some results recently reported from two sources in England. Crowdy and Wain (1951), working at Long Ashton Research Station and Wye College, approached the problem with three points in mind—(1) that a systemic fungicide must not be phytotoxic, (2) that it must be readily translocated in the plant, and (3) that it must be inhibitory to fungi. They considered that ease of translocation might be the most difficult requirement to meet, so they decided to investigate the phenoxyacetic acid series. Several well-known selective weed-killers belonging to this series, such as "Methoxone" and 2:4-D, are well-known to be readily translocated in plants; they are also mild fungicides. Crowdy and Wain sought to find whether it was possible to devise a molecular configuration which would not possess the specific plant growth-regulating activity of the herbicides but which would retain the ease of translocation and antifungal activity. They found that 2 : 4 : 6—trichlorphenoxyacetic acid approximately filled the requirements. Applied to broad bean plants through the roots it gave promising control of *Botrytis fabae* infection of the foliage.

In all these researches one can infer from the protective effect observed that the substance applied is being translocated and acting as a fungicide in its new site. That inference is conceivably wrong and is certainly not sufficiently well supported by experimental evidence. We have already considered the possibility that application of the " fungicide " may so alter host metabolism as to make it unsuitable for development of the pathogen. Another possibility is that in its passage through host tissues the substance applied may be metabolically altered, perhaps radically, leading to the formation of some other substance which exerts the final observed protective effect. Several workers have suggested that this may take place as systemic activity is by no means always highly correlated with *in vitro* fungicidal activity. In this connection results reported by Brian, Wright, Stubbs and Way (1951) are of interest. They worked with an

antifungal antibiotic (produced by the common soil fungus *Penicillium nigricans*) known as griseofulvin (Brian, 1949). This substance disorganises growth of certain fungi, producing certain easily recognised and specific morphogenitic changes. By bioassay 0.1 microgram can be detected. They were able to show that if this substance was applied to the roots of plants growing in water-culture, sand culture or in soil, a substance could subsequently be detected in the tissues of stems and leaves possessing the same unusual properties; this substance appearing in the stems and leaves is in all probability unchanged griseofulvin or some very closely related compound. Plants treated with griseofulvin showed little, if any, damage. Good control of several plant diseases has been observed:—early blight of tomato (*Alternaria solani*), mildew of barley and oats (*Erysiphe graminis*), *Botrytis fabae* on broad beans and *Botrytis cinerea* on lettuce. Griseofulvin, unfortunately, is rapidly decomposed in soil by microbial activity.

It is perhaps worth mentioning here that control of bacterial disease of plants by systemic treatment has also been achieved. Well-known antibiotics, such as penicillin, streptomycin and aureomycin, have been found effective in control of crown gall (*Bacterium tumefaciens*) and Dimond, Stoddard and Chapman (1952) have found several synthetic materials active against bacterial blight of dwarf beans (*Xanthomonas phaseoli*).

LONG TERM PROSPECTS

It is now clear that compounds with systemic fungicidal activity can be found. It is also clear that the great difficulty is going to be to find an effective compound which is harmless to the plant. The effective systemic fungicide, to a greater extent than is necessary with conventional fungicides, must be specific in its toxicity. No fungicides in use today are really specific in action. All are generally toxic substances and at high dosages are almost invariably phytotoxic; fortunately the phytotoxic level is usually sufficiently greater than the effective fungicidal level to enable them to be used safely, but, as we have seen, the margin of safety is likely to be less with fungicides applied systemically. Specificity in fungicides must be based biochemically on specific interference with enzyme-catalyzed metabolic processes specific to fungi. Unfortunately, the more closely related two organisms are the more likely they are to possess similar enzyme complements. Thus, for instance, fungi and higher plants being more closely related than insects and higher plants, it is likely to be much more difficult to find a specific systemic fungicide, harmless to plants, than to find a non-phytotoxic systemic insecticide. Moreover, our knowledge of fungus physiology is so exiguous that it is not possible at present to point to any metabolic processes which are specific to fungi and so afford starting-points for rational research on specific fungicidal activity. The nearest approach to a truly specific fungicide is the substance griseofulvin, mentioned above, which is believed

to depend for its activity on interference with a growth-regulating mechanism specific to fungi (Brian, 1949). Further research on systemic fungicides is thus inevitably bound up with fundamental investigations of fungus physiology.

Let us assume that this research will be successful. What then will be the advantages of a systemic fungicide? An answer to this question will at present necessarily be highly speculative, but perhaps of some interest. Four main advantages can be envisaged :—

(1) It may be expected that even application of the fungicide will not be essential, since parts missed at the time of application will be subsequently protected by translocation. In this connection it should be noted that almost all experimental work so far reported has been based on root treatment, as a matter of convenience. This would rarely be a suitable method of application in practice; application to the foliage would be more practical but it is uncertain at present whether any of the known systemic fungicides can be effectively applied in this way. A particularly interesting possibility would be the protection of roots against soil-borne pathogens as a result of application of a systemic fungicide to the foliage. This would seem to be dependent on finding a systemic fungicide which can be translocated downwards through the phloem. Most of those so far investigated appear to travel mainly through the xylem and therefore most effectively upwards from root to shoot.

(2) Young growing parts, formed *after* an application of the fungicide, may be protected as a result of translocation. This may well be possible since such data as are at present available suggest that systemic fungicides do tend to accumulate in growing points. But, while growing points may thus be protected, it seems probable that this will be at the expense of older organs from which the fungicide has been withdrawn.

(3) It may be possible to obtain effective disease control under conditions of very heavy rainfall when conventional surface fungicides are rapidly leached away. Against this one needs to note that the protection afforded by systemic fungicides is not indefinitely prolonged, either as a result of dilution by distribution over newly formed host tissue or as a result of metabolic destruction of the fungicide in host cells. Neither must one forget that the rate of uptake of the fungicide by the plant will be almost certainly greatly affected by environmental conditions.

(4) It may be possible to control systemic diseases, such as the vascular wilts, which have proved so resistant to any means of treatment. The Panama disease of bananas (*Fusarium cubense*) is a notorious example of such a disease.

Against these potential advantages one must place the hazards which may arise from the introduction of biologically active substances into food crops, particularly if highly persistent. The hazard will be decreased in so far as the fungicide used is truly specific in its action.

CONCLUSION

The present status of systemic fungicides may be summed up in the following propositions :—

(1) Substances with systemic fungicidal activity have now been found.

(2) Research is still in an early stage.

(3) Practical experience of disease control in the field by such means is almost completely lacking and may well remain so for some time yet.

(4) Until this practical experience has been obtained speculation about the value of systemic fungicides should be cautious.

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RECENT BRITISH DEVELOPMENTS IN TAINT-FREE USE OF BHC

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Paper presented at the XIIth International Congress of Pure and Applied Chemistry, New York, September 10th—13th, 1951, and subsequently published in " Agricultural Chemicals," Vol. VI, No. 12, December, 1951. Reprinted by kind permission of the Editor of " Agricultural Chemicals " and the Author.

ALTHOUGH first publication of the insecticidal use of benzene hexachloride (BHC) took place within the last decade, its exact history is not well known. Internal records at the Hawthorndale Laboratories, Jealott's Hill Agricultural Research Station in England, show that tests in 1937 proved it to be quite active, but this observation was neither published nor followed up. It was also tested with interesting results in France in the early years of World War II, but no distinction appears to have been noted between the insecticidal activities of the various isomers. Serious work began in England in 1942, when derris supplies were threatened by the Japanese, and in the following year it was becoming apparent that only the gamma isomer had really outstanding properties, as reported by Slade (1) in 1945.

Since that time the number and volume of the outlets for BHC have increased enormously, but the agricultural uses have been limited in many important directions by its liability, in some forms and under some conditions, to cause off-flavour, or " taint," in food crops. Isolation of substantially pure gamma-BHC (lindane) has helped not only by lowering the taint potential at a given level of insecticidal performance, but by making possible new techniques of application.

We in Britain have developed the taint-free use of BHC in three main directions :—

(1) by developing gamma-BHC formulations,
(2) by using gamma-BHC in new techniques, and
(3) by using even crude BHC for certain purposes according to a carefully timed schedule.

THE TAINT PROBLEM

Before considering these items in detail let us look a little more closely into the general problem of taint. BHC, or impurities contained in the technical grade, are capable of causing taint or a musty flavour in some crops. It has tended to become routine to ascribe any off-flavour, particularly in potatoes, to BHC. BHC can and often does taint potatoes grown in soil treated with it; but it is not by any means the only culprit. Farmyard manure applied to potato soils can cause taint in dry seasons, at least in England, and the writer knows of several instances of complaint where potatoes had been grown in soils which have never been treated with BHC.

Distinction must also be drawn between two kinds of taint; that due to the presence of BHC, its impurities or breakdown products, *within* a plant, and taint due to the presence of BHC *on* crops at harvest time. Some crops—potatoes, onions, perhaps carrots and certainly black currants—are capable, through their foliage or roots, of absorbing BHC, which afterwards remains and is translocated within the plants. Other crops—cereals, apples, plums, tomatoes, strawberries and mushrooms—do not seem to absorb the chemical at all or, if they do, do not exhibit taint. It must be repeated, however, that if BHC applications to crops in this second list are so timed that BHC is still physically present on them at harvest time, then taint will occur. Timing must be such that normal weathering, including volatilization, will remove spray deposits before harvest.

There are other complicating factors involved in pursuing this subject :—

(1) of any group of people attempting to differentiate between normal and tainted fruits or vegetables, about 40 per cent lack a critical palate and are quite incapable of distinguishing the two,

(2) some sorts of produce appear normal under some conditions, yet tainted under others; tainted potatoes, unless the tainting is very heavy, are not usually detected in the fried state, though most distasteful when boiled, and,

(3) some fruits, peaches for example, may seem quite normal when eaten fresh or stewed, yet may develop taint after canning.

In Britain, the first field tests of BHC were carried out in 1942 and work on the taint problem started two years later. Results from seven years' work are thus available. Much of this work was carried out by specially selected "tasting panels" consisting of at least twelve workers, frequently more, and by methods capable of statistical analysis.

The methods of tasting now developed are very sensitive and, both at the Hawthorndale Laboratories already mentioned, and at our own Fernhurst Research Station, the flavour of test material is placed in one of five categories :—

Category A—normal,
B—very slightly abnormal but palatable,

Fig. 1.—The effect of treating oats with the combined organo-mercury/gamma BHC seed dressing, 'Mergamma' A.
The crop from untreated seed sown in the background was severely attacked by wireworm. The crop from treated seed in the foreground escaped damage.

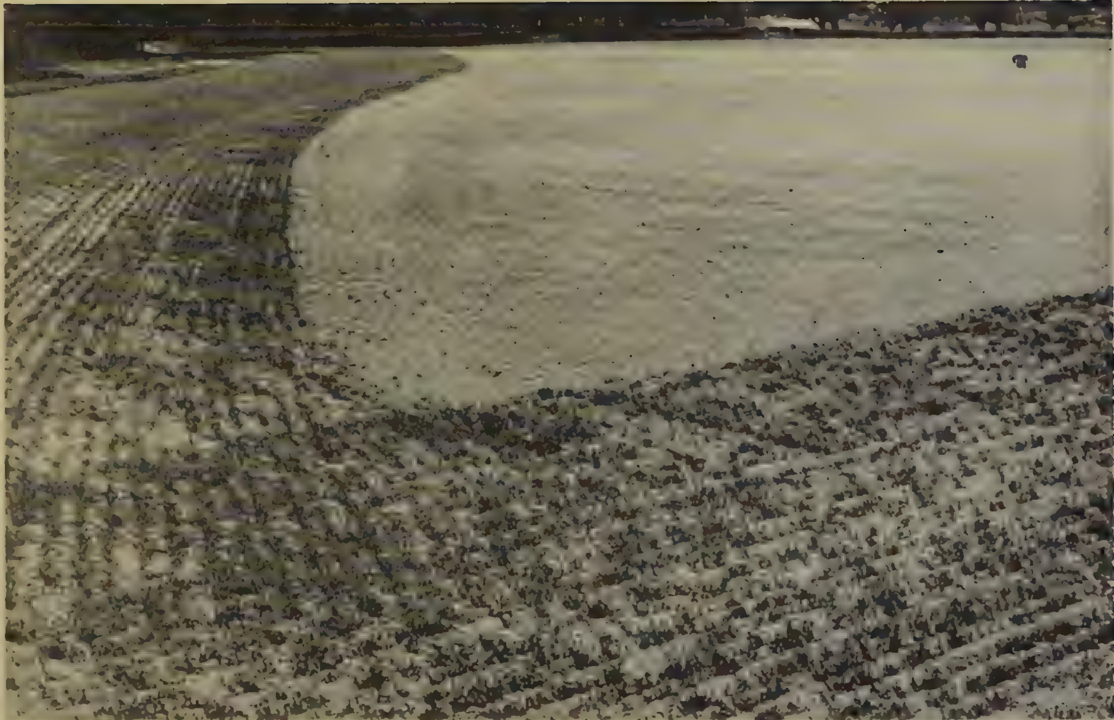

Fig. 2.—The bare area in the centre of this Yorkshire field was sown with oats which had not been treated with any seed dressing. The seed sown in the remainder of the field was treated with the combined organo-mercury gamma BHC seed dressing 'Mergamma' A.

C—almost disagreeable,
D—definitely disagreeable and
E—objectionable (inedible).

It should be added that carefully planned tests in a canteen, in parallel with tests by the tasting panel on the same lots of potatoes, have shown that degrees of tainting can be detected by the panel that would pass unobserved in normal consumption. For example, canteen tests seldom detect anything abnormal until Category C is reached.

CROPS INVOLVED

One of the biggest uses of BHC in Britain is for the control of wireworms (*Agriotes* spp.) attacking cereals and sugar-beet, particularly in soils newly broken from old pasture (Jameson et alia) (2), (3). There is no record of cereals ever having been tainted. There is a suspicion that fresh sugar-beet may occasionally have been tainted, but even if this is so the taint certainly does not persist through the complicated refining processes into the final sugar.

Potatoes grown in land previously treated with BHC dusts on other crops, broadcast or by a combine drill, are very liable to be tainted for some years afterwards. A normal dressing for broadcast treatment is 6 lb. of crude BHC (13 per cent gamma-BHC) suitably diluted per acre and, under these conditions, we have said that potatoes must not be grown on the land in the two following years. We now know that under some conditions this period may not be sufficient—for reasons which follow. Combine seed drill treatment uses one-third to one-half as much (2 to 3 lb. BHC) per acre and it is probable that the danger period is reduced somewhat. Jameson and Tanner (4) have recently provided a critical appraisal of this aspect of the problem.

As a matter of interest the taint susceptibilities of four typical potato varieties in England increase in the order :—King Edward, Arran Banner, Majestic and Eclipse.

There is a further complication. A rate of application of BHC which, *if applied evenly*, is quite unlikely to cause taint in following crops, can readily cause patchy taint in those crops if the application is *uneven*. Surface treatment, e.g. for the control of flea beetle (*Phyllotreta* spp.), is not so dangerous as where the same amount of BHC is worked into the soil.

Treatments involving the use of crude BHC for the control of carrot fly (*Psila rosae*) have occasionally caused taint, but it seems likely that this will be overcome by the use of formulations based on pure gamma-BHC.

Crude BHC can be used quite successfully and without taint on top fruits, as will be shown in a more detailed statement later in this paper.

The story is quite different with black currants. These are particularly susceptible to taint from BHC and must not be sprayed or dusted

with it under any circumstances. This also means that top fruits must not be sprayed with BHC if black currants are grown as an under-crop.

The case of mushrooms is rather curious. One might have expected a crop with such a delicate flavour to be susceptible to taint, yet application of BHC dusts is widespread for the control of various insect pests and we have had no single report of taint. It is recommended, however, as a safeguard, that such applications should be made after a heavy picking. Similarly, BHC spray products have been used quite extensively on glasshouse tomatoes at all stages yet, again, there has been no report of trouble. On the contrary, onions, with a very strong natural flavour, can fairly easily have this flavour impaired by BHC applications.

GAMMA-BHC FORMULATIONS

Production of the substantially pure gamma-BHC at a reasonable cost proved difficult for some time, and even today it is necessarily an expensive chemical. So much so that it cannot be considered for such operations as control of locusts and malarial mosquitoes, where low cost is of first importance and taint problems negligible or non-existent.

On the other hand gamma-BHC has proved technically satisfactory in experiments, and commercially acceptable to growers, either where the crop involved will stand the high costs of application per acre, e.g. on flower bulbs, or where the discovery of new techniques has enabled very small and therefore inexpensive amounts of gamma-BHC to do a worthwhile biological job, e.g. on cereals.

One of our distinctive early contributions came in the field of the new techniques—the use of combined organo-mercury/gamma-BHC seed dressings. However, in our field experience, even pure gamma-BHC has tainted such a root crop as potatoes and such fruit as black currants. It is true that it gives a different taint from that of crude BHC, but nevertheless it is a taint. Fortunately, this seldom appears at insecticidally satisfactory rates of application, but it does limit the amounts applied or the time of application in certain directions.

Specifically, we find that 0.5 lb. per acre of pure gamma-BHC is the minimum for effective control of ordinary populations of wireworms in potato soils. But because such an application made just before planting may cause taint, we have found it necessary to use this amount either in the autumn previous to planting or in two halves spread over two seasons. It is true that this particular finding was based on work using a grade of BHC containing 90 per cent gamma-BHC, but we find that the purest form of gamma-BHC approaching 99.9 per cent can also cause taint.

SEED DRESSING TECHNIQUES

The conventional organo-mercury cereal seed dressings used in Britain are almost exclusively about one fourth the strength of

American dressings, but are used at four times the rate, i.e. at 2 oz. per bushel. Early in our work it occurred to one of the writer's colleagues that we should test seed dressings containing gamma-BHC. Even with the British rate of application of dressing and, further, our generally higher rate of seeding of some 2½ to 3 bushels per acre, it seemed inconceivable that any worthwhile effect could be produced by the minute amounts of gamma-BHC that could be made to adhere to the seed. Nevertheless the experiments proceeded and it was discovered that as little as one-twelfth to one-fifth the previous minimum amount of gamma-BHC per acre could, by the new technique, give substantially complete protection of cereal crops against wireworm attack, in addition to the normal benefits of control of many seed-borne and some soil-borne fungi.

The earlier work in this direction has been reported by my colleagues Jameson, Thomas and Woodward (2) and Jameson, Thomas and Tanner (3), and such combined dressings have been used commercially in Britain for the three full seasons 1948/49 to 1950/51. Following is a summary of the later technical findings both from field experimentation at our Fernhurst Research Station and from our critical observations on many hundreds of farms throughout Britain.

So far as technical performance is concerned we estimate, in round figures, that broadcast treatments with BHC of the order of 6 lb. per acre give a 90 to 100 per cent protection of cereals from heavy wireworm attack, and extra tillering ensures a full crop. With combine drill applications the protection may be 80 to 100 per cent, while the gamma-BHC seed dressing may not be quite so good, say 70 to 100 per cent. On the other hand the seed dressing application has cut costs in Britain to something of the order of one-sixth the cost of broadcast treatment, and made it worthwhile for farmers to use the seed dressing as a measure of insurance wherever wireworm attack is anticipated.

To summarize the relative amounts of gamma-BHC used in, and the farmer's costs of these various methods of treatment, the following table is presented :—

Treatment	*Oz. gamma BHC/acre*	*Relative costs*
Broadcasting	12	6
Combine drilling	4—6	2—3
Seed dressing	1	1

In addition to field experimentation my colleagues have visited a great many farms on which combined organo-mercury gamma-BHC seed dressings have been used, particularly with a view to investigating any suggestions of failure. It is of interest to learn that in the 1949/50 season only 0.05 per cent of the estimated acreage treated with these dressings showed complete failure ; 0.15 per cent of the area showed some thinning of plants despite the applications ;

and the total number of complaints reported involved an area of 0.42 per cent of the total.

It was found that a few of the instances involved damage by leatherjackets (*Tipula* spp.) which are not controlled by such means. Of the remainder, a full analysis showed that the few failures were due to one of three causes, or a combination of them, as follows :—

(1) where the farmer had failed to obtain a satisfactory seed bed, mainly due to excessive roughness and lack of consolidation, seed dressings were not able to exert their full effect,

(2) where seeding rates had been reduced appreciably below the normal for the areas concerned, or the seed had been inefficiently drilled, then some trouble arose, and

(3) where the wireworm population was really excessive, for example, a million or more per acre, then the new chemical tool was not adequate to give full protection.

It was also clear from the investigation that where differences occurred, spring sowings gave better results than autumn sowings ; the product showed better effects on medium or light soils than on heavy soils ; and that the poorer results were more evident on land after permanent grass than on any other class of land.

It may be added that, in our experience, emergency treatment of a crop already showing wireworm damage with a surface application of BHC does not give satisfactory economic results ; such applications are worthwhile only if made before or at the time of seeding.

TOP FRUIT SPRAYS

In discussing top fruit sprays, it should be remembered that some of the English fruit pests are different from those in North America and, even among those common to both countries, the relative importance of some is quite different. Speaking of our British conditions, the insects concerned on, for example, apples are :—

Apple blossom weevil	*Anthonomus pomorum*
Winter moth and other caterpillars	*Operophtera brumata*, *Monima incerta*, *Hybernia defoliaria*, *Cacaecia podana*, etc.
Aphids	*Anuraphis roseus*, *Aphis pomi* etc.
Apple sucker	*Psylla mali*
Apple capsid	*Plesiocoris rugicollis*
Wooly aphis	*Eriosoma lanigerum*
Apple sawfly	*Hoplocampa testudinea*
Fruit tree red spider	*Oligonychus ulmi*
Codling moth	*Cydia pomonella*

The conventional treatments against this range of pests hitherto have been the use of tar and/or petroleum emulsions during the dormant season, or DNC/oil washes in the delayed dormant period, to control aphis, sucker and to some extent capsid and red spider, followed by lead arsenate to control caterpillars ; nicotine or derris

for the control of sawfly, followed by lime-sulphur or derris for red spider; and lead arsenate again for second brood codling moth. Some difficulty was always experienced in the control of apple blossom weevil, woolly aphis and sawfly.

With the advent of DDT, the apple blossom weevil problem was solved and this insect is no longer a major pest in the fruit orchards of Britain. Following up this lead our own work has concentrated more on BHC than on DDT and we have found that, using a dispersible powder formulation containing 50 per cent BHC, itself containing a minimum of 13 per cent gamma-BHC, we can now control a wider range of these insects than with any other alternative programme available.

The complete spraying programme currently recommended is :—

lb. 50% *BHC per 100 galls*	*Stage of Growth*	*Insects Controlled*
4	"Bud burst"	Apple blossom weevil
4	"Green cluster"	Caterpillars, aphids and sucker
4	"Pink bud"	Capsid and woolly aphid
2—3	"Petal fall"	Apple sawfly

It seems inappropriate here to give many tables of confirmatory data, but as apple sawfly was for many years our most difficult pest, because timing of the then available insecticides was so critical, I would select a typical result with this insect from our 1950 records. The 50 per cent BHC dispersible powder was applied at 4 lb. per 100 gallons at "green cluster" and at 2 lb. at "petal fall", the latter being the effective application. The sawfly counts were taken on June 10th, with the following results :—

APPLE SAWFLY COUNTS

Treatment	*Apples Examined*	*Sawfly Attacked*	*Per cent attack*
50% BHC	2598	4	0.15
Parathion (0.005%)	2138	13	0.6
Lime sulphur (twice)	1512	35	2.3
Control	754	80	10.6

In the case of woolly aphid, the timing of BHC sprays is different from the old method on the woolly colonies. The best time is just after the aphids emerge from hibernation as the days get warm. The "green cluster" application is effective but "pink bud" timing is probably better. The same timing is best for apple capsid.

None of these applications show any control of red spider mite, possibly even the reverse. This programme has become possible only since the advent of the phosphorus insecticides, particularly parathion, which enables this mite to be controlled later in the season. Similarly, BHC is not efficient against codling moth and neither it nor DDT is recommended in England because of effects on parasites and predators of red spider.

The interesting part about this programme is that it completely avoids any danger from taint, on apples and plums at least. In the last three seasons (up to 1950), involving experimental applications to something like 4,000 acres of commercial top fruit in Britain, there has been no instance of taint.

Summarizing our new BHC apple spraying programme, I would say that it economizes labour, because it cuts out winter treatments and is applied with the fungicide wash; it is not applied to a set schedule in case the insects appear later, but is modified according to which insects prove numerous in a particular season; there is less lost time during the spring spraying; and it is cheaper than the older programme.

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THREE EXPERIMENTS IN WITCHWEED CONTROL

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Reprinted from "The Empire Journal of Experimental Agriculture", Vol. XX, No. 78, *April*, 1952, *by kind permission of the Editor and the Author of the article.*

THE common Witchweed of the Sudan is *Striga hermonthica* Benth., and is a widespread parasite of dura (*Sorghum* spp.), dukhn (*Pennisetum typhoides* (Burm. f.) Stapf and Hubb.) and other grain crops. Only locally, however, does it become the great menace to cultivation which it constitutes in parts of South and East Africa. Losses are nevertheless caused by it annually, and, in efforts to reduce these, much work was carried out by Andrews (1, 2). With the advent of the hormone weedkillers hopes were raised that a solution to the problem might be found, and a successful experiment was carried out during the 1947 season in which significant increases in straw (and by implication in grain, which was eaten by birds) were obtained by treating sorghum growing on heavily infested land with 1 and 2 lb. per feddan* of MCPA as sodium salt (3). At the time the price of grain was so low that native economy could not stand the cost of the treatment. Since then, however, the price of the chemicals has fallen, especially since the advent of 80 per cent. 2, 4-D† (sodium salt) powder, and the price of grain has risen sharply. It was decided that the experiments were no longer of merely academic interest, and work was resumed in the 1951 season.

The spraying of weedkillers on the emergent Striga plants will give an effective kill of the parasite, but since it has by then done most of the damage of which it is capable during the course of building up its food reserves before flowering, the only benefit of the treatment is in reducing the amount of seeding. In the 1947 experiment the sorghum was sprayed with both strengths of the MCPA at 14 and 28 days after sowing before any Striga had appeared. In this manner, the MCPA was washed into the soil and killed many of the parasites before they could injure the cereal.

The three experiments to be described here were all carried out on irrigated sorghum; the first at Nuri Pump Scheme in Northern

* 1 feddan = 4,200 sq. metres = 1 acre approx.

† Also known as DCPA.

Province, the second at the Gezira Research Farm, and the third on the White Nile at Fatisa. Of these sites, the first and third were heavily infested naturally; the second had been heavily infested artificially during previous Striga experiments.

NURI PUMP SCHEME

An area, 45 x 60 metres, was laid out in nine plots of 15 x 20 m. Sowing of sorghum, variety Abu Saba'in, was followed 15 days later by the spray treatments. These were :—

A. 1 lb. per feddan MCPA as sodium salt.
B. 1 lb. per feddan 2,4-D as sodium salt.
C. Control, no spray.

All spray rates are calculated as equivalent weight of MCPA or 2,4-D acid. No uninfested control plots were obtainable. The dates of operations were: sowing 15.5.51; spraying 30.6.51; harvest 25.9.51.

Striga plants first started to make their appearance on July 14, and then visible infestation increased steadily until August 19, when the plants were pulled, counted, and weighed, and removed from the plots. Results are given in Tables 1 and 2, where it will be seen that the actual incidence of Striga, by three criteria, was reduced to about one-third as a result of either treatment.

TABLE No. 1

Percentage of Sorghum Holes infested with Striga at Nuri.

Date	Treatment		
	A	B	C
14.7	1	1	2
21.7	6	6	17
28.7	17	24	50
4.8	19	25	67
11.8	36	31	78
18.8	37	31	79

In Tables 1—3 the differences between treated and controls are highly significant. The differences between the treatments are not significant.

TABLE No. 2.

Fresh Striga Plants per feddan at Nuri, pulled 19.8.51.

Treatment	Weight	Numbers
	rotls	
A	524	63,322
B	493	57,022
C	1,333	124,600

As the actual area of the experiment was smaller than the irrigable field in which it took place, the surrounding land was sown at the same time by local cultivators, with sorghum of the same variety. As it became obvious towards the end of the experiment that little or no grain could be expected, the straw was cut for fodder. That their pessimism was fully justified may be seen by reference to Table 3, in which are given the yields per feddan of sorghum under the various treatments. There were no statistical differences between the effects of the two chemicals. The yields of heads were low, but the variety is one esteemed principally for its high yield of straw, and the yield of heads was fairly comparable with that from neighbouring areas that were not locally considered too infested to be used for sorghum cultivation.

TABLE No. 3.

Yields of Sorghum at Nuri, harvested 25.9.51.

	A	B	C
No. of heads per feddan	10,920	17,682	Nil
Wt. of heads per feddan (rotls) ...	554	594	Nil
Wt. of straw per feddan (rotls) ...	11,700	11,240	4,496

GEZIRA RESEARCH FARM

This experiment was designed to compare the effects of MCPA and 2,4-D sodium salts at two strengths, viz. 1 lb. and 2 lb. per feddan. Unfortunately the chemical in this case killed or severely damaged most of the sorghum plants. Re-sowings were, of course, useless for several weeks after the application of the chemical, and so the experiment was abandoned.

Spraying was carried out 14 days after sowing. After a further week it was obvious that extensive injury had been caused to the crop by all spray treatments. Plants treated at the lower rate were extensively yellowed, and many of those treated at the higher rate were either heavily burned or killed outright. After one week more, several of the plots were completely bare of crop.

The reason for this result is obscure; no other cases have come to the author's notice of such killing of sorghum by hormone weed-killers. It is, however, suspected that a contributory cause lay in the abnormally dry season. No rains had fallen in the Gezira to wet the soil before the time of sowing; the demand on the irrigation water was increased. Only light waterings could be given, and the drying power of the atmosphere was very great. The plants, at the time of spraying, were under a heavy water strain at a time of high transpiration. Under such circumstances it might be expected that the plant's uptake of the solution sprayed on its leaves would be rather high, and that its uptake of the solution washed in at the next watering would also be high. Further experiments are contemplated.

FATISA PUMP SCHEME

In conjunction with the other two experiments described above, which were carried out directly by the staff of the Gezira Research Farm, it was decided by the White Nile Schemes Board to try the chemicals on some of the tenancies badly infested with Striga on the Fatisa Pump Scheme. The sorghum was sown by the tenants in the normal manner and spraying was then carried out by the agricultural staff using knapsack sprayers. Most of the sorghum was of the Feterita variety, with the exception of a pair of tenancies on which was grown Wad Fahl.

As the tenant's holding of 2½ feddans was in most cases the unit of treatment, the only comparison available was usually between it and the untreated holding (belonging to another tenant with possibly different standards of cultivation) alongside. At harvest, a measured area of 1 feddan was cut within the treated area and compared with the yield from a similar feddan from the neighbouring untreated holding. Since the treated holdings were widely scattered, and since dates of sowing and spraying varied widely, the best guide to the relative yields is given by the yield of the treated plot as " percentage of control."

Yields are given in Table 4. The variety was Feterita except in Hoshas 262 and 261 where the Wad Fahl variety was grown. With much Feterita an economic increase in yield was obtained, in addition to a reduction in the amount of infestation. In no case was the increase in the yield of Feterita heads less than 9.6 per cent., representing 138 rotls,* and in straw of 9.2 per cent., representing 362 rotls. These two lowest increases were obtained at the highest rates of spray, possibly as a result of damage from the spray. The yield of the Wad Fahl variety was severely reduced. This appeared in the field to be partly the result of actual damage by the chemical, resulting in early lodging and thinning of the stand, and partly due to severe aphid attack (to which this late maturing variety is rather prone), the insects being apparently more partial to the treated plants.

It appears that the best results in this experiment were obtained at the 1½—2 lb. rate per feddan of the 80 per cent. material, i.e. between 19 and 26 oz. of 2,4-D acid equivalent, and that good control of the Striga, at least in terms of the percentage of infested holes, was obtained as a result of all times of spraying up to 28 days. In general the later the date of spraying the lower the degree of control obtained.

DISCUSSION

It seems that a satisfactory solution to the Witchweed problem may at last be in sight, at least as far as certain varieties of dura are concerned. Varieties of sorghum which, like Wad Fahl, seem to be intolerant of the hormone sprays, will have to be reserved for clean ground, but the rest, such as Feterita and Abu Saba'in, will not only yield an economic crop, but will show an increase in yield such as

* 1 rotl = 450 gm. = 1 lb. approx.

will pay the cost of the spraying during the same year. Clean ground with no Striga is, of course, the ideal aim, and it is not impossible that by a consistent policy of spraying every grain crop in a rotation the incidence of Striga may be progressively reduced to somewhere near that point, especially if seeding of the surviving parasites can be prevented.

TABLE No. 4.

Data of Fatisa Experiment.

Hosha No.	Rate in lb. p.f.*	Sowing date 1951	Sprayed days after sowing	No. of heads per feddan	WT. of heads r.p.f.	WT. of straw r.p.f.	Striga % holes
263	¾	1.9	20	24,120	1,087	2,195	1.1
264	0	1.9	...	23,019	860	1,532	42.6
Yield as % of control			...	104.8	126.5	143.2	3.0
262†	1½	1.9	20	28,370	2,970	5,544	1.0
261†	0	1.9	...	47,720	5,335	5,674	8.2
Yield as % of control			...	59.5	55.7	97.7	12.0
135	1½	28.7	28	16,452	1,025	3,481	14.0
135	0	28.7	...	8,800	443	3,018	55.7
Yield as % of control			...	187.0	231.3	115.3	25.0
324	2	6.8	14	43,754	1,566	3,729	16.3
323	0	6.8	...	31,740	1,030	1,773	75.9
Yield as % of control			...	137.9	152.0	210.3	21.0
249	2	30.7	35	24,210	1,101	3,760	25.9
248	0	30.7	...	13,430	569	2,072	46.5
Yield as % of control			...	180.3	193.6	181.5	55.7
250	2½	30.7	34	15,928	1,613	4,285	27.5
251	0	30.7	...	40,200	1,140	3,922	50.8
Yield as % of control			...	39.6	141.5	109.2	54.1
325	2½	6.8	14	40,639	1,572	4,276	20.0
326	0	6.8	...	15,870	1,434	3,668	94.0
Yield as % of control			...	256.1	109.6	116.6	21.7

† Wad Fahl variety.

'**No. of heads**' is a very variable estimate of yield, as the effect of closer spacing is to produce more and smaller heads, though the weight remains roughly constant over a considerable range of spacings. Note in particular Hoshas 250-1 and 325-6.

* In this instance the spray rate was calculated on the commercial 80 per cent sodium salt. The actual rate of application, calculated as acid, was only 80 per cent of the amount shown.

The anomalous result given by Gezira Research Farm experiment requires considerable study. The probability seems to be that it was the result of a combination of unusual conditions, but should it be, as suspected, the result of the plants' treatment at a time of heavy water strain, caution is indicated in the application of the method to crops grown not under irrigation but under rainfall, where the liability to drought is much greater.

Summary.—Three experiments are described which were carried out in the Sudan in 1951 against *Striga hermonthica* Benth.

Two of these gave excellent control of the parasite as a result of spraying the sorghum host crop with hormone weedkiller between

14 and 28 days of sowing. Less satisfactory control was obtained as a result of spraying at 35 days after sowing. Not only were fewer holes infested on the treated plots but appreciable increases in grain and straw yield were recorded.

The third experiment was a failure, the sorghum being killed by the weedkiller.

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TULL, TILLET AND BUNT

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Reprinted from "Agriculture" Vol. LIX, No. 5, *August*, 1952, *by kind permission of the Editor and the Author of the article.*

NOWADAYS bunt disease of wheat is so effectively controlled by seed dressing that it is difficult to appreciate the magnitude of the problem it presented in Europe in bygone days. By the same token we are apt to overlook the debt we owe to Tull and Tillet, whose patient investigations into its cause and cure some two hundred years ago laid the foundation of our present immunity.

Tull, Tillet and Bunt is not, as it might appear to be, a firm of family solicitors. The first two words are the names of men who, two hundred years ago, contributed much to the improvement of agriculture; bunt is the disease of wheat. Jethro Tull in England, who had introduced the horse-hoe and seed drill, examined the disease; Matthieu Tillet in France ascertained the cause and popularized its cure. It is interesting and instructive to reflect on the work of these pioneers.

Today, this fungus disease is of little importance because its control, by the simple process of dressing seed with organic mercurials or other products, is a routine matter. Two hundred years ago, bunt attacks were so severe that in a bad year half the grain could be lost, and even in a good one many crops had sufficient bunt to give the detested violet shade and characteristic smell to the flour, which so much lowered its price. The making of ginger-bread is said to have originated from the fact that, at that time, it was a means of disposing of bunted grain.

Many thinkers, philosophers and farmers speculated on the cause of bunt, and among them was Jethro Tull, who is, of course, famous for his book, *Horse-hoeing Husbandry* (1731 and 1733). In his book, which did so much to increase harvests, Tull had a chapter on "Smuttiness," and he showed, by means of some rather primitive experiments, that he believed the condition to arise from excessive wetness in the soil. The importance of this chapter was, however, that he gave a remedy, which was to dress the seed with lime and salt. He told the story, from hearsay, of the grain ship sunk in the Bristol Channel, and the salvaged grain, which, when sown, produced perfectly healthy crops, whilst other fields nearby were badly diseased. One gets the impression that Tull did not really believe the story of the shipwreck, and he issued the *caveat* that the salvaged grain might have grown clean even without the sea salt, since it was a case of "change of seed," another method he advocated to ensure healthy crops.

Matthieu Tillet was a prominent French official in the town of Troyes, where he became Master of the Mint. He had a small farm, an inquiring mind, and became a member of the Academy of Science at Bordeaux. The enormous loss caused by bunt led this body in 1750 to offer a prize for the best essay on the subject, and it was this which inspired Tillet to carry out his really remarkable experiments in the winter of 1751-52—exactly two hundred years ago—and in the two subsequent winters.

We now know that bunt is a fungus disease perpetuated by means of spores on the skin of seed grain, or sometimes in the soil. These spores germinate in the ground and enter the young seedlings there; they then grow within the plants until spores are reproduced again in the ear in the form of the familiar black bunt-balls and dust.

Though we may smile in a superior manner at many of the outrageous theories put forward to account for the disease in the early eighteenth century, we cannot but respect the exacting experiments laid out by Tillet so long ago, which show almost every feature of a modern " replicated " or " randomized " field trial. Tillet was familiar with Tull's work, and, in fact, with Duhamel du Monceau, who translated *Horse-hoeing Husbandry* into French. But he by no means accepted Tull's theory of the cause of bunt, maintaining that there was insufficient evidence in a single, small experiment to prove it, although he admitted that any or all of the current theories could be true. These were that it was caused by dampness; by a " miasma " in the air; by not changing the seed; by using certain manures, such as sheep dung; by the sun falling on wet ears; and by many other causes save only the dust of bunt itself. Tillet's experiments were consequently designed with two main objectives; first, to discover the cause of the disease, and secondly, to find a cure.

Tillet's Experiments. His first experiment, laid down in October and November 1751, consisted of a hundred and twenty different plots, each 18 feet by 5 feet. It contained four different manurial treatments and a control, or no-fertilizer plot, six different sowing dates and seven different seed treatments. These were: (1) pure, clean seed; (2) naturally bunted seed; (3) pure seed dusted with the black bunt dusts; (4) a mixture of (2) and (3); (5) seed treated with nitre and lime; (6) seed treated with salt and lime; (7) seed treated with lime alone. The whole experiment was in four rows each 540 feet long, with the blackened, undressed seed down the outside of one row of plots.

Reading Tillet's book, published in 1755, one can sense the tremendous excitement with which he watched the corn on the plots form clean and bunted ears. The presence of about two-third infection of bunt in his infected seed plots and its almost entire absence in the others led him to believe, as he says, " that a virus resides in the black dust," which was transmitted to the seed. He took no crop records from the individual plots but only from the different manurial

MONSIEUR TILLET'S EXPERIMENT, 1752-53

(Autumn-sown wheat in all 120 plots, each 18 feet × 6 feet)

Tillet's Plot Numbers	No. of Plots	Fertilizer Treatment	Seed Treatment	No. of Bunted Ears per Plot			No. of Healthy Ears per Plot	REMARKS
				Highest	Lowest	Average		
1, 6, 11, 16, 21, 31, 36, 41, 46, 51, 54, 56, 61, 66, 71, 81.	16	None	Clean seed, untreated	11	1	4.3		In effect, the control plots.
2, 3, 7, 12, 13.	5	Farmyard manure: horse dung and clean straw.	Ditto	14	1	5.4		
4, 5, 8, 14, 15, 52, 53	7	Farmyard manure: horse dung and infected straw.	Ditto	49	11	35		
9, 17, 18	3	Farmyard manure: sheep dung and clean straw.	Ditto	94	1	38	3,475	1% infection
10, 19, 20	3	Farmyard manure: sheep dung and infected straw.	Ditto	879	10	571	2,439	19% infection
32, 33, 34, 35, 42, 43, 44, 45, 57, 79, 80	11	None	Seed dusted with bunt powder sometimes after coating seed with gum.	1,687 938			2,026 331	Plot 42 (45% infection). Plot 45 (74% infection). Remaining plots had a maximum of 75% and a minimum of 33⅓% infection.
37, 38, 72, 73, 78	5	None	Seed dusted with bunt powder, then dressed with salt and lime.	10	A few			Less than 1% infection.
39, 40, 77	3	None	Seed dusted with bunt powder, then dressed with nitre and lime.	4	Very few			Less than 1% infection.

treatment blocks. They did not differ much from the control, but he was satisfied that his disease-free plots gave twice as much grain per *arpent** as the ordinary crops in the neighbourhood that year.

The success of the 1751 experiment led him to repeat the trial on a bigger and more elaborate scale in the winter of 1752-53. This time the plots were larger and to some extent randomized, and at the harvest he carefully counted the number of healthy and attacked ears in most of the plots. He also included several varieties of wheat, some oats, barley and ryegrass. Some plots had dung made from clean straw and others had dung from straw which had borne bunted ears. The same seed treatments were used, but additional plots were laid down to see if the smuts of oats and barley could be transmitted to wheat.

Again, reading Tillet's careful description of the trial, one feels the excitement and pleasure he experienced in the unfolding of this remarkable experiment which, in spite of his own and those popularly held but completely false theories, led him to an inescapable conclusion. His feelings are illustrated by the following quotation from his preface : " Perhaps the best method of freeing men from an untrue hypothesis is not to demonstrate its falsity by a methodical analysis through the use of simple reasoning, but to state that one was oneself once of this same false opinion, but that it has been abandoned with reluctance as incapable of further tenure."

It is not possible in this article to give details of the results from his 120 plots, but the table on page 27 summarizes some of them.

There could be no doubt from this experiment that both his objects had been achieved. With what great satisfaction he must have written : " the usual cause, the abundant origin of this bunted wheat, is in the dust of the attacked grain . . . the preparations I used have guaranteed the most highly infected grain from the effects of the contagion, and the results are yet more marked when it is considered that the seed, when treated, always had on it much of the black dust with which it had been powdered."

A Practical Approach.

Tillet, although he had a detached scientific attitude to experiment, was a strictly practical man : he did not wish to indulge in philosophical speculations as to the basic causes of bunt but to be of service to agriculture, as a final quotation from his remarkable book will show : " Most of these remedies cost nothing : I repeat exactly nothing : others cost a little : all are practical. I have often felt that the farmer, who is often poor and reluctant to change his ways might be unwilling to face even a slight cost or the trouble of a special procedure. I have therefore tried to follow his vein of economy, to adapt myself to his customs and to be useful to him without crossing him."

Tillet never had any idea that he had to deal with a fungus, and it is perhaps unfortunate that he ruled out " philosophical speculations," as he would have found out the truth, seeing that he had already

* Formerly the French acre = approx. 1¼ English acres.

EXPERIENCES DE 1752-53. . . . .

. . . . 5 Epis cariés 3 Charbonnés. 31	. . . . 2 Epis cariés. 2 Charbonnés. 36	. . . . 3 Epis cariés. 3 Charbonnés. 41	. . . . 3 Epis cariés. 46
FROMENT pur, humecté avec une eau de Gomme, & noirci de carie. $\frac{1}{5}$ Au moins d'Epis cariés. Planche maigre. 32	FROMENT pur, noirci de carie, humecté, mariné-chaulé en cet état, & n'ayant rien perdu de la carie. 10 Epis cariés. 3 Charbonnés. Assez belle. 37	FROMENT pur, noirci de carie à sec, & enterré à fleur de Terre. 566 Pieds sains. . . . 1026 Epis sains. 491 Pieds malades. . 1687 Epis cariés. 1057. 2713. 42	FROMENT sali de poussiere d'Ivraie, cariée, & enterré à fleur de Terre. Affectée comme 42, 43, 44 & 45. mais moins. Plus de retard dans les marques de la carie. 47
FROMENT pur, humecté avec une eau de Gomme & noirci de carie. $\frac{1}{4}$ D'Epis cariés. 5 Charbonnés. 33	FROMENT pur, noirci de carie humecté, mariné-chaulé en cet état, & n'ayant rien perdu de la carie. 8 Epis cariés. 3 ou 4 Charbonnés. Belle. 38	FROMENT pur, noirci de carie à sec, & enterré à un ou deux pouces de profondeur. $\frac{1}{3}$ Au moins d'Epis cariés. 6 Charbonnés. Moins belle que la précédente. 43	FROMENT pur, sali de poussiere d'Ivraie, cariée, & enterré à 1 ou 2 pouces de profondeur. 778 Pieds sains. . . . 2194 Epis sains. 363 Pieds malades. . . 898 Epis cariés. 1141. 3092. 48
FROMENT pur, humecté avec une eau de colle de Poisson & noirci de carie. $\frac{1}{4}$ Ou à peu près d'Epis cariés. 34	FROMENT pur, noirci de carie, humecté, nitré-chaulé en cet état, & n'ayant, &c. 3 Epis cariés. Quelques Charbonnés. Belle. 39	FROMENT pur, noirci de carie à sec, & enterré à 3 ou 4 pouces de profondeur. $\frac{1}{4}$ D'Epis cariés. 5 Charbonnés. Moins belle que la 43^e^. 44	FROMENT pur, sali de poussiere d'Ivraie, cariée, & enterré à 3 ou 4 pouces de profondeur. $\frac{1}{3}$ D'Epis cariés. 49
FROMENT pur, humecté avec une eau de colle de Poisson & noirci de carie. $\frac{1}{4}$ D'Epis cariés. 35	FROMENT pur, noirci de carie, humecté, nitré-chaulé en cet état, & n'ayant, &c. 4 Epis cariés. 3 ou 4 Charbonnés. Belle. 40	FROMENT pur, noirci de carie à sec, & enterré à 5 ou 6 pouces de profondeur. 70 Pieds sains . . . 151 Epis sains. 211 Pieds malades. . . 918 Epis cariés. 281. 1169. 45	FROMENT pur, sali de poussiere d'Ivraie, cariée, & enterré à 5 ou 6 pouces de profondeur. 318 Pieds sains. . . . . 903 Epis sains. 344 Pieds malades. . . 998 Epis cariés. 662. 1901. 50
IVRAIE cueillie dans un Champ où s'étoit trouvé beaucoup d'Ivraie attaquée de la carie. 463 Epis sains. 1 Epi carié 464. G	SEIGLE pur en Terre pure. 175 Epis sains. H	SEIGLE pur en Terre noircie de carie de Froment. 32 Epis sains. 1 Ergot. I	SEIGLE pur, noirci de carie de Froment. 144 Epis sains. 4 Ergotés. K

12 Pieds.

Premiere division contenant 4 rangées d'Orge pure.

Point de maladie.

6 Pieds.

DEUXIE'ME Partie du Terrein labouré à la Charue, ayant les mêmes proportions que la 1^ere^.

Même Grain que dans la Premiere Partie; avec cette différence qu'il avoit été fortement noirci de carie le 4. Octobre, qu'on l'avoit laissé ainsi sali & renfermé dans une Boëte jusqu'au 24. du même mois, jour auquel il fut bien lavé, exposé au Soleil pour y sécher, & semé le lendemain ainsi nétoyé. On voyoit cependant sur la houpe de ce Grain lavé, à l'aide de la moins forte l'houpe du Microscope, quelques particules de carie que les lotions n'avoient point enlevées.

R E' S U L T A T.

Assez belle: Un grand nombre d'Epis cariés.

Fig. 3.—Portion of a page of M. Tillet's book showing layout of experiments.

noticed the similarity between bunt and the dust inside old puff-balls. Nevertheless, his work had tremendous practical results. Treating seed grain with salt and lime, rotting urine or similar substances, became common, and increased Europe's crops enormously, so that soon his successors, the Abbot Tessier and M. Prevost, were to find better seed dressings. The mycologist Tulasne eventually described the fungus, and called it *Tilletia* in honour of the early French experimenter.

Today, when we still have need to increase our food production, we cannot afford to neglect the example of those two painstaking research workers, Tull and Tillet, and it is to be hoped that we continue to find people with the inquiring minds yet matched by practical approach to problems which were once found in those two men.

REFERENCES

1. **M. Tillet.**—Dissertation sur la Cause qui corrumpt et noircit les Grains de Bled dans les épis ; et sur les moyens de prevenir ces accidens. Veuve, Pierre Brun, Bordeaux, 1755. British Museum No. 461. f. 28.
2. **J. Tull.**—" Horse-hoeing Husbandry." G. Strahan, London, 1733-40, British Museum No. 7074.m.3.

TECHNICAL BREVITIES

This section includes information on plant protection problems in their widest sense, which has been obtained from published literature. We give references to the publications concerned.

INSECTICIDES

Pollen Beetle and Seed Weevil Control.

In France, the seed weevil *Ceuthorhynchus napi* appears on brassicas earlier than *C.assimilis* and pollen beetles (*Meligethes* spp.) later still. Should only the first pest be present, one dusting is enough; but two are needed if the others also occur. Because treatment must be given from the end of March to end of April when the weather is often cold and wet the insecticides used must be able to kill the pests within 48 hours. This rules out rotenone, pyrethrum, phenothiazine, and DDT. An efficiency of 95 to 100% is given by dusting with 8% BHC at 60 kg. per ha. or, 30 kg. per ha., with 15% BHC, 2% parathion. 2.5% aldrin, or 2.5% dieldrin.

Bonnemaison, L., *Phytoma*, 1951, (27-28): 6-10.

Sugar Cane Pest Control.

For control of greyback cane beetle, *Dermolepida albohirtum*, in Queensland, growers are now using a 20% BHC dust at 75 lb. per acre instead of a 10% dust at 150 lb. per acre, thus saving one third of the cost. In 1949, 20,000 acres were treated. One application in the half-open drill after the setts have germinated and stooled adequately gives a complete protection through the normal cycle of three crops. Neither dividing the dressing between plant cane and the first ratoon nor mixing the BHC with fertilizer gives any advantage. Control of the early instars of French's cane beetle, *Lepidiota frenchi*, was obtained with a 10% BHC dust at 150 lb. per acre, but 300 to 400 lb. per acre was needed against third-stage grubs. The army worm, *Cirphis unipunctata*, was completely prevented from invading cane areas by putting down a barrier of 10% BHC dust 6 to 9 in. wide; a successful alternative was a 0.13% DDT spray at 25 gal. per acre. Use of BHC-fertilizer mixtures has effectively prevented attack by the wireworm, *Lacon variabilis*. BHC has not been successful against the mound-building ant, *Aphenogaster pythia*, or against earth pearls, *Magarodes sp.*

Mungomery, R. *W.*, 50*th Rep. Bur. Sug. Exp. Stas., Qd.* 1950: 38-41.

Grass Caterpillar Control.

Oxycanus cervinata and *O. despectus* are the chief species of the subterranean grass caterpillar or porina damaging pastures in New Zealand and distinction is drawn between the pests and grass grub, *Odontria* sp. Effective control is given by BHC in superphosphate. Rates of 3¼ and 6½ lb. BHC (13% gamma isomer) in 1 cwt. supers per acre gave 55 and 80 % better control respectively than Paris green bait. Recently BHC of 10% gamma isomer strength has been marketed for use at 5 and 10 lb. per acre, and a mixture of 5 lb. BHC (10% gamma isomer) in 1 cwt. supers is also available. The lower dosage is for grazing land and the double dose for small-seed production areas where maximum control is wanted. On lawns, use may be made of 50% DDT at 1½ lb. per 1,000 sq. yards in a suitable fertilizer or sand, or of BHC (10% gamma isomer) at 2 lb. per 1,000 sq. yards. The BHC, though four times as effective as DDT in the first year, is less effective than DDT in the second.

Kelsey, J. M., N.Z. J. Agric, 1951, **83** (3): 195-200.

Orchard Spray Schedule: Effect of BHC on Red Spider.

Observations and experiments in orchards in the U.K. show that BHC does not cause build-up of red spider. Parathion can be relied upon to destroy red spider, and its use along with the usual fungicides after BHC at pre-blossom and petal-fall has continued to give satisfactory results since the programme was introduced in 1950. If parathion is disliked, use is recommended of DNC/oil or straight petroleum oil for red spider, followed by BHC against other pests and by a supplementary spraying of derris in June for red spider.

Stapley, J. H., Grower, 1951, **36** (20): 1025-1029.

White Grub Control on New Strawberry Land.

In Indiana, elimination of white grub is necessary on new ground to be used for strawberries. Three years trials show that BHC is satisfactory whether applied to the sod before ploughing or to the surface of freshly ploughed ground and disced in. Addition of DDT to BHC was no benefit. Chlordane and lead arsenate were inferior and the latter treatment was very expensive. When BHC 12% gamma isomer at 30.2 lb. per acre was disced in to freshly ploughed land and the plants were set out next day, high yields of U.S. No. 1 grade berries were obtained in the following spring. No mention is made of taint.

Marshall, C. E., J. econ. Ent., 1951, **44** (5): 668-671.

Peach Tree Borer Control.

In New York, parathion gives better control of the peach tree borer, *Sanninoidea exitiosa*, than DDT. Tree sprayings at 21-day intervals of parathion at 2 lb. of 15% wettable powder per 100 gal. are also effective against the lesser peach tree borer, *Synanthedon pictipes*, which can attack any injured portion of the trunk. A programme of four sprayings of parathion is suggested for control of both species.

Smith, E. H., J. econ. Ent., 1951, **44** (5): 685-690.

Earwig Injury to Apple Fruit : Relation to Brown Rot Infection.

In W. Midland apple orchards, U.K., injury to fruit in late summer by earwigs (*Forficula auricularia*) can be an important precursor of brown rot (*Sclerotinia fructigena*). There is no previous record of earwigs causing primary injury to fruit. Tree banding with sacking soaked in 10% BHC and dusting the bands and tree bases weekly with 5% BHC during August trapped and destroyed many earwigs and showed that earwig injury and amount of brown rot are closely correlated. Although banding was fairly effective it is cumbersome. Other methods of earwig control should be sought.

Croxall, *H. E.*, *Ann. Appl. Biol.*, 1951, **38** (4) : 833-843.

Wheat Shield Bug Control.

In Syria, the wheat shield bug locally named " Souni," *Eurygaster integriceps*, is a serious pest of wheat against which BHC and other insecticides have proved unsatisfactory. Field experiments show that 0.75% and 0.8% parathion dusts are very efficient at 75 kg. per ha. but not economical. The 0.8% dust applied by knapsack duster at 15 to 17.5 kg. per ha. gave only a 20% reduction. Using a 6 h.p. duster on a Jeep fitted with a drag sheet and applying a 0.75% dust at 48 kg. per ha. gave 70% control.

Talhouk, *A. S.*, *Bull. ent. Res.* 1951, **42** (2) : 375-377.

Heteronychus Beetle of Wheat Control : Seed Dressing with BHC

In Kenya, promise of effective control on a large scale of the synastid beetle, *Heteronychus consimilis*, is indicated by insecticidal trials. This beetle is a major pest of wheat, and great damage is done by adults killing the plants by chewing young shoots just below the ground and by larvae feeding on the roots. High adult kills, marked reduction in damage, and increased yields were obtained either by applying aldrin at 7.2 oz. per acre with the fertilizer at sowing time or by seed dressing with BHC as ' Mergamma ' A at 10 oz. per 200 lb. of seed wheat. Seed dressing with ' Agrocide ' 7 (2.6% gamma-BHC) at the same rate was rather less effective. Inferior treatments were ' Agrocide ' 3 (0.6% gamma-BHC) at 8 lb. 5 ozs. per acre applied with fertilizer or dusted on to the ground 24 days after sowing when the wheat was 4 in. high. ' Agrocide ' wettable powder (6.5% gamma-BHC) used as a bran bait gave poor results.

Le Pelley, R. *H. and Goddard. W. H.*, *Bull. ent. Res.*, 1952, **43** (2) : 403-406.

Capnodis Beetle Control.

In toxicity tests in Israel neither BHC nor DDT were effective as fumigants against boring larvae of the *Capnodis* beetle. Used as contact insecticides, high kills were given by 5% BHC and by a mixture of 1% chlordane + 3% Thanite, but the BHC was effective at the end of a 50-day period whereas chlordane-Thanite lost its effect after 30 days. DDT was far less effective. Larvae did not survive after passing

through a 1 : 9 sand-insecticide layer, using either 5% BHC, 5% dieldrin, or 5% methoxychlor, and these insecticides remained effective for over a year when left undisturbed in the ground. Against adult beetles a spray containing 0.5% BHC wettable powder gave a kill comparable to that obtained with cryolite. No injury was caused to 6-year old plum and peach trees from 5% BHC applied to soil around the trunks at a depth of 5 cm. using 100 g. per tree.

Rivnay, E., Bull. ent. Res., 1951, **42** (3) : 567-573.

Garden Chafer Ecology and Control.

Life history and ecology of the garden chafer, *Phyllopertha horticola*, in the U.K. is described in detail. Poor permanent grassland is the natural habitat of this pest. Adults emerge suddenly in May or June according to the weather, and the flight period lasts 3—4 weeks. Eggs are laid in groups, mostly in the top 3 in. of soil. The larvae feed in the root zone but go deeper in winter to hibernate. Grass roots are destroyed and soil aggregates are broken down. Field populations were reduced by ploughing and reseeding. Promising chemical control was obtained by dusting with 3.5% BHC at 70 lb. per acre against adults during the flight period.

Raw, F., Bull. ent. Res., 1951, **42** (3) : 605-646.

Cabbage Seedpod Weevil Control.

In California, complete control of the cabbage seedpod weevil, *Ceuthorhynchus assimilis*, the grubs of which cause serious losses of brassica seed, was obtained by weekly dustings of 1% technical BHC or 1% dieldrin, but the BHC also gave about 95% control of the cabbage aphid, *Brevicoryne brassicae*, against which dieldrin was ineffective. A 1% lindane dust, though not quite so effective in control, was considered to be preferable to BHC since it is safer and less likely to cause soil contamination. The work indicates that treatments can be reduced to about four, applied at 10 to 12 days intervals.

Carlson, E. C., J. econ. Ent., 1951, **44** (6) : 958-965.

Narcissus Bulb Fly Control.

In the U.K., over the past two years 16% of the Cornish bulb crop has been attacked by narcissus bulb flies, involving a loss of £100 per acre. Dusting with BHC reduces this loss by two-thirds at a cost of £14 per acre. The BHC acts against all the vulnerable stages—adult, egg and young larvae—whereas DDT affects only the adults. Dusting should start at the beginning of the flight period (about 20th April) and continue into June, giving usually five treatments. It is important to drive the dust from an overhead position into the crack in the soil round the neck of the bulb. Should the bulbs be left down for two or more years, the amount of BHC in the soil may cause taint to a following potato crop. Resting places of flies and bulb trays should also be dusted.

Grower, 1952, **37** (12) : 676-678.

Grasshopper Control: Low-Volume Spraying.

In New York State, excellent control of hoppers of the red-legged grasshopper (*Melanoplus fermurrubrum*) was obtained by low-volume (20 gal. per acre) and low-pressure (40 lb. per sq. in.) sprays of 7 different insecticides. Outstandingly good were BHC at 0.2 lb. gamma-isomer per acre. and dieldrin and aldrin at 0.2 lb. actual toxicant per acre closely followed by toxaphene.

Marshall, D. S., J. econ. Ent., 1951, **44** (4): 615-616.

Earth Mite Control on Pastures.

In New South Wales red-legged earth mites attacking pastures were wiped out by top dressing from a seed drill with ½ lb. pp DDT mixed with 90 lb. superphosphate per acre.

Gellatley, J. G., Agric. Gaz. N.S.W., 1951, **62** (10): 526.

Tests of Lindane and other Insecticides for Control of Lygus oblineatus.

In tests with 14 insecticides at low, medium and high concentrations against the tarnished plant bug, *Lygus oblineatus*, on Chinese cabbage in a Michigan State College greenhouse, lindane, chlordane and parathion gave 100% control at high concentration and lindane was significantly better than parathion, TEPP and nicotine + pyrethrum + sulphur in field experiments for the control of the same bug on Chinese cabbage. Lindane was also the most effective on celery, a most important factor affecting both yield and quality of crop being the number of applications of the product.

Zia-ud. Din., J. econ. Ent., 1951, **44**: 773-9 (*via Hort. Absts.*, 1952, **22**, 2, p. 210).

Control of Cabbage Pests: Are Cabbage White-Butterfly larvae resistant to DDT?

Complaints from growers that 2% DDT and 2% BHC dusts, used successfully since 1945 for controlling cabbage moth (*Plutella maculipennis*) and cabbage white butterfly (*Pieris rapae*) failed to control white butterfly larvae on their crops were investigated in the Maitland, Gosford and Windsor districts of New South Wales. The investigators could find no evidence that larvae were more difficult to kill than in 1945, but larger larvae were difficult to control with the recommended dosage. DDT was found in laboratory tests to be more effective as a contact insecticide than as a stomach poison on the larger caterpillars, and application of 1—2% DDT dust or 0.1% DDT spray every 3 weeks (every 2 weeks in summer and early autumn) or of 2% BHC dust every 2 weeks are recommended. A dust containing 1% DDT and 2.5% nicotine controlled a heavy infestation of slaty grey aphids, which was destroyed by 5% nicotine dust.

G. Pasfield, Agr. Gaz. N.S.W., **62**: 477-80 (1951) (*via Chemical Absts.*, **46**: 7: p. 3207 *Apl.* 1952).

Cereal Smut Control: Seed Treatment Status in Manitoba.

A survey over 1947-1949 revealed that only 47% of farmers treated oat and barley seed for smut control. About 13% of these used such older and less effective disinfectants as copper sulphate and formaldehyde. The others used organic mercurials. About 55% of farmers that treat seed used seed-treating machines and thereby obtained better smut control (0.72% smut left in fields) than those using the shovel or auger (1.32% smut left in fields). Effectiveness of the organic mercurials increased with the number of days post-treatment storage, thus, the 35% of farmers who stored their treated seed for 3 days or less before sowing had 1.07% smut in their fields, whereas the 65% who allowed 4 days or more in storage had only 0.27%. Regular seed treatment with efficient disinfectants properly applied gave almost smut-free crops.

Cherewick, W. J. and Popp W., Sci. Agric., 1951, **31** (11): 496-504.

Septoria Leafspot of Tomato Control.

Better control of Septoria leafspot on tomato was obtained in Indiana by spraying with copper fungicides (basic copper sulphate or copper 8-hydroquinolate) than with ziram or zineb. Yields per acre of tomatoes were 20 to 23 tons from the coppers alone or copper alternating with ziram, whereas those treated with ziram or zineb alone yielded 11 to 16 tons, and untreated plants only 7 tons.

Samson, R. W., 63rd. Rep. Ind. agric. Exp. Sta. 1950: 35.

Jute Stem Rot Control.

Jute stem rot, caused by *Macrophomina phaseoli*, is a serious disease of jute in Orissa, India. It is seed- and soil-borne. Seed dressing with 'Agrosan' GN using 4 tolas per seer of seed and crop spraying with 0.25% 'Perenox' or 1% Bordeaux mixture are recommended.

Mohanty, U.N., *Indian Fmg.*, 1950, **11** (9), 400-403.

Blister Blight of Tea Damage: Crop Losses and Spraying Benefit.

Yield records from yield experiments at St. Coombs, Ceylon, show that, over the past four years, the loss of the tea crops from attack by blister blight (*Exobasidium vexans*) averaged 20%. St. Coombs is not one of the worst blight areas. Other experimental data at St. Coombs confirm this rate of loss and show that weekly spraying gave almost complete protection whereas there was a 4.9% loss of made tea from crops sprayed fortnightly and 23.5% loss from unprotected areas.

Portsmouth, G. B., *Tea Quart*, 1951, **22** (2): 90-92.

Gladiolus Corm-Borne Disease Control: Corm Curing.

Best control of corm-borne diseases of gladiolus was obtained by curing the corms at 35°C immediately after digging, which encourages

periderm and cuticle to develop ahead of invading organisms, and by use of a fungicidal dip before planting.

Bald, J. G., Phytopathology, 1951, **41** (10): 935.

Seed Dressing of Vegetables.

Twenty-eight materials including copper salts, organo-mercurials, quinones and thiocarbamates were tested as seed protectants on peas and lettuce in laboratory (plate tests), glasshouse and field. Cuprocide, Spergon, Panogen, thiram, ferbam, Dow 9B (zinc trichlorophenate) and 36L (nitrosopyrazole) gave the most promising results in the soil tests under various conditions of soil moisture. High moisture appeared to reduce the efficiency of certain materials and low moisture appeared to increase the phytotoxicity of others.

Jacks, H., N.Z. J. Sci. Techn. Sec. A., 1951, **33** (3): 27-38.

Apple Scab Control: Efficiency of Wettable Sulphurs.

In New York, results are reported of ten years orchard testing of sulphur fungicides for apple scab control. Ground wettable sulphurs increase in effectiveness as particle size decreases. They should have a particle size of less than 5 microns. Under conditions favourable for scab, at least 4 to 5 lb. actual sulphur of the best sulphur material is required per 100 gal. Paste forms of wettable sulphur are more effective than dry forms.

Addition of Orthex helps to give better protection when wettable sulphurs are applied during rain. Hydrated lime increases the rate of setting and retention of wettable sulphurs. Oil-type stickers also improve their effectiveness under some conditions. Although wettable sulphurs are protectants only, the pastes give as good scab control as lime-sulphur on an equal sulphur basis when weather conditions favour scab development. All sulphurs can cause severe injury should very high temperatures occur before rain, but lime-sulphur has caused so much injury that it is now recommended only to eradicate scab during the infection period or after the lesions are fully developed. To avoid injury caused by high temperature or the use of insecticides which are incompatible with sulphur, and to control diseases other than scab, use may be made of copper ammonium silicate and zinc or ferbam.

Hamilton J. M. and Palmiter, D. H., *Bull., N.Y. St. agric. Exp. Sta.*, 747, 1951: 1-63.

WEEDKILLERS AND HORMONE PRODUCTS

Cacao Viruses.

As a result of preliminary experiments the use of sodium arsenite for the removal of redundant forest trees which are alternative hosts of cacao viruses has been adopted as a routine measure at the West African Cacao Research Institute, Tafo, Gold Coast.

The method employed is the insertion into a girdle cut in the tree of a strong alkaline, concentrated solution of the chemical diluted to 10% with starch paste.

Ann. Report West Afr. Cacao. Res. Inst., April, 1949 to *Mar.* 1950, 84 *pp.*, 1951, *via* R.*A.M.*, **31**, 5, *May*, 1952, *p.* 232.

Field Notes on Use of the Herbicide IPC.

Horticultural crops tolerant to the grass-killing selective herbicide, isopropyl N phenyl carbonate, include peas, safflower, bulbs, mint, strawberries and certain vegetables.

Wilson, J. R. *W., Agric. Chemls.*, 1951, **6** : 2 : 34-7, 91-7 (*via Hort. Absts.* 1951, **21**, 3, *p.* 358).

T.C.A.—A Promising New Weedicide for Grass Control.

T.C.A., a contact, non-selective herbicide, kills grasses slowly, underground rhizomes taking 2 to 3 months to die. In N.S.W. its main use at present appears to be as a substitute for sodium chlorate for grass control, the advantages of using T.C.A. instead of sodium chlorate being,

(1) the shorter period of soil sterilization,

(2) reduced fire hazard, and

(3) higher toxicity to plants. Its cost, however, is at least twice that of sodium chlorate.

Green, K.R., Agric. Gaz., N.S.W., 1950, **61** : 455-6 (*via Hort. Absts.*, 1951, **21**, 3, *p.* 359).

Hormones Kill Horsetail.

The application of 2.5 pt. MCPA (' Agroxone ') dissolved in 10—15 gal. of water at a rate of 10 gal. per acre, using a low volume spraying outfit, destroys marsh horsetail or snake-pipe (*Equisetum palustre*).

Plant, W., Fmr. and Stk. Breed., 1952, **66**, 34-5. (*via Field Crop Absts.*, 1952, **5**, 3, 169).

Couch or Twitch.

Control measures against the 3 species, *Agropyron repens*, *Agrostis tenuis* and *Arrhenatherum elatius* include full or bastard fallowing, stubble, cleaning, ploughing, where possible to a depth of 15 to 18 inches, hand-digging of couch on the field borders and application of 2—3 cwt. per acre of sodium chlorate.

Min. Agric. and Fisheries Adv. Leaflet 89 : 1951 : *pp.* 4 (*via Herbage Absts.* : **22** : 2 : 1952, *p.* 4.)

MISCELLANEOUS

Insect Attractants : Sexual Scent Substances in Lepidoptera.

The attractancy to male Lepidoptera for scents secreted by the females is reviewed and discussed. The substances may attract species

or genera, though probably not over distances of several kilometres as stated by some observers. Many species secrete the scents throughout their whole life. Extraction of the scents by solvents is easy and the extracts retain their attractiveness for a long time, but the chemical composition of the scents has not yet been determined. Use has been made of them for alluring and annihilating males, thus preventing propagation, and their analysis and synthesis is desirable with a view to their practical application in this way.

Götz, B., *Experientia*, 1951, 7 (11): 406-418.

Locust Swarm Movement: New Forecasting Hypothesis.

Meteorological studies indicate that the major movements of swarms of the desert locust (*Schistocerca gregaria*) take place towards areas of convergence (i.e. areas where inflow of air exceeds outflow and the overall vertical motion of air is one of ascent) and swarms may be expected to collect in the vicinity of such areas. The hypothesis is thought to merit consideration as a means of forecasting swarm movement. Convergence may explain the frequent association of heavy rains with the arrival of locusts, and may also contribute to gregarization by producing a concentration of adult solitaria from long distances into areas suitable for breeding.

Rainey, R. C., *Nature*, *Lond.*, 1951, 168 (4286): 1057-1060.

PRINTED IN ENGLAND BY
THE CLUNBURY PRESS,
BERKHAMSTED, HERTS.
J 1-6793